FIRE LOSSES AND JUSTIFIABLE PROTECTION COSTS IN SOUTHERN PIEDMONT OF VIRGINIA

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FOREWORD

This report is a summary of a much longer report of the first study of the economic limits of forest fire control, made in the Southern Piedmont of Virginia. The long report was prepared to present exhaustively the details of methodology used to derive both cost and loss data, as a guide to future studies of this nature. It will not be circulated but those interested in further details of the study are invited to correspond with this Station concerning it.

The authors acknowledge gratefully the invaluable assistance given them by the late Virginia State Forester, Mr. Fred Pederson, and his successor, Mr. George Dean, and their staff; by the State Commission of Game and Inland Fisheries, State Park Commission, and officials of the State Agricultural Experiment Station at Blacksburg. Special acknowledgments are due Mr. C. O. Handley, Leader, Virginia Cooperative Wildlife Research Unit, and Mr. Donald S. Wallace, Chief, Division of Water Resources for Virginia, for advice and comments on the wildlife and water phases of the study, respectively.

Within the Appalachian Station, valuable data and advice were given by the Forest Survey staff. Dr. Charles R. Hursh, in charge of Forest Influences research, cooperated actively in both field and office analyses of the water phases of fire effects.

TABLE OF CONTENTS

Foreword

Page

Introduction and Summary..... 1
The Case Study-Area..... 3
The Fire Situation..... 5
Costs of Fire Control..... 6
Losses from Fire..... 8
  Timber damage..... 9
  Watershed damage..... 11
    Flood, sediment, and erosion damages..... 11
    Water-yield losses..... 13
  Wildlife and recreational damage..... 16
  Other damage..... 18
  Summary of damages..... 19
Determination of Justifiable Protection Cost..... 19
Implications of Findings..... 24
Applicability to Other Areas..... 26

FIRE LOSSES AND JUSTIFIABLE PROTECTION COSTS

IN SOUTHERN PIEDMONT OF VIRGINIA

INTRODUCTION AND SUMMARY

Forest fire control has now come into its own as a highly organized form of cooperative enterprise. Although far too large an area still lacks even the minimum of protection, nevertheless the acreage under organized protection has attained considerable extent, embracing, in 1944, 301 million acres of private and state forest lands throughout the United States. Moreover the old "rule-of-thumb" protection practices no longer satisfy fire control administrators. Instead, there is developing a body of systematic procedures hammered out of the accumulation of years of hard and often bitter experience, aided by the findings of research workers in various branches of the field.

The spread and intensification of protection effort has not been achieved without increased costs. Thus the total of combined federal, state, and private expenditures has risen from $6,710,000 in the fiscal year 1931 to $15,099,000 in 1944 for the protection of state and private forests. Although in general such additional expenditures are known to have reduced the losses from fire, the specific extent to which given applications of increased costs have brought about reductions in loss has not heretofore been evaluated. Today, with estimates of "adequate" statewide protection cost for all forest states varying from 18 million dollars to more than 25 million dollars per annum, state foresters, Forest Service officials, legislators, and the taxpayers are becoming more aware than ever before of the need for such analyses.

Simply stated, the problem is how to approximate more closely protection needs for stated conditions and areas, and more particularly how to insure that each additional dollar of outlay will return at least an equivalent reduction in fire damage.

The solution to this problem requires the determination of costs and corresponding losses at various protection levels. The starting point is to find out what is being accomplished today; i.e., to appraise the losses being suffered at the current average expenditure level. Next it is necessary to determine how much further we can expect to reduce losses by means of additional expenditures. The final step is to compare the combinations of cost plus loss for each of the different levels considered and to select that one which is least in amount. The cost side of

this "least cost plus loss" combination is the measure of the "justifiable" limit, or most economical level, of protection effort. It represents that point beyond which any additional unit of outlay will return less than an equivalent value in the form of reduced damage. The principle involved here is the same as that which any good enterprise manager applies in his efforts to obtain the maximum net return on his investment.

This report presents the methods and results of such an analysis for the Southern Piedmont of Virginia based upon data obtained primarily for fiscal years 1940-43.1/ In this investigation attempt is made to recognize and evaluate, to a reasonable degree, all costs contributing to fire control, by whomever incurred, and all losses to individuals and the public interest arising out of damage to the several resource values at stake.

In brief, the results are as follows:

(1) Total average annual protection costs, adjusted to 1943 price levels, now average about 1.9 cents per acre protected.

(2) Average annual burn is 0.57 percent.

(3) Total adjusted annual monetary losses average about 7.9 cents per acre protected.

(4) Assuming existing organization and efficiency, the most "economical" protection level is represented by an average annual total expenditure of 4.0 cents per acre, or some 2 cents more than at present.2/

(5) At this level, average annual losses per acre protected would be reduced to at least 4.1 cents, or some 3.8 cents less than now, and

(6) Area-burn would be reduced to 0.30 percent, a reduction of 0.27 percent.

(7) On basis of the above, to reduce the area-burn-percent (hence damages) any lower would not yield results commensurate with the additional cost.

1/A similar study is under way in the Pacific Northwest.

2/In recognition of the fact that change may occur in price level and in other conditions affecting the values at stake and the costs of protection, the findings of this report apply only to a 5-year forecast period, 1944-48, inclusive. At that time it will be necessary to recheck the findings as the basis for further forecasts.

In conclusion, this investigation establishes a benchmark of justifiable protection cost for one specific homogeneous area. Therefore the quantitative results cannot directly be applied to areas of different characteristics and problems. Some may justify higher, others lower costs depending upon the difficulty of protection and the values at stake. It would be too large an undertaking to attempt to examine in detail each section of a state. It does appear feasible, however, to select units representing altogether the scale of variations within a region. Once estimates are made for such "type" areas, a series of benchmarks will have been established from which justifiable expenditure limits for all portions of a state can be derived and a statewide "area-cost" total thus obtained.

THE CASE STUDY-AREA

For purposes of this case study, a homogeneous unit was selected consisting of seven counties--Brunswick, Charlotte, Halifax, Henry, Lunenburg, Mecklenburg, Nottoway--in the bright-leaf tobacco section of the extreme southern portion of the Virginia Piedmont, with a total area of 2,344,000 acres, of which 1,402,000 acres (60 percent) are forested (fig. 1). Farm woodlands comprise 935,000 acres (67 percent of total forest area); only 1,300 acres are publicly owned. The remainder is owned largely by non-residents, including local townspeople. The average forest holding is small--45 acres in the case of farm woodlands, rarely over 200 acres in any case. Corporate ownership is extremely limited. Chief soils are the Cecil-Appling group, with smaller areas of the Georgeville-Alamance group, Herndon, and Wilkes soils. Most of this unit is within the Roanoke River drainage and is subject to damage from erosion, flood waters, and sedimentation, and in common with the rest of the Piedmont suffers from serious water shortages related to land-use conditions.

The principal forest types, from east to west, are loblolly pine-hardwoods (13 percent of total forest area), shortleaf pine-hardwoods (25 percent), Virginia pine-hardwoods (23 percent). Within the last two types, past cutting and fire have removed the pine component over considerable areas so that upland hardwoods now occupy 33 percent. Bottomland hardwoods occupy only 6 percent (fig. 1). Average stand per acre, all conditions, is 1,400 board feet, indicating marked understocking. Average annual net increment is only 116 board feet, or 0.62 cord, per acre. Drain exceeds growth in the softwoods and in the total forest volume, although in the hardwoods there is a small excess of growth over drain. Principal commodity drain is for lumber, fuelwood (including flue-wood for tobacco curing), and pulpwood.

Figure 1. MAJOR FOREST TYPES

SOUTHERN PIEDMONT STUDY-AREA

LEGEND

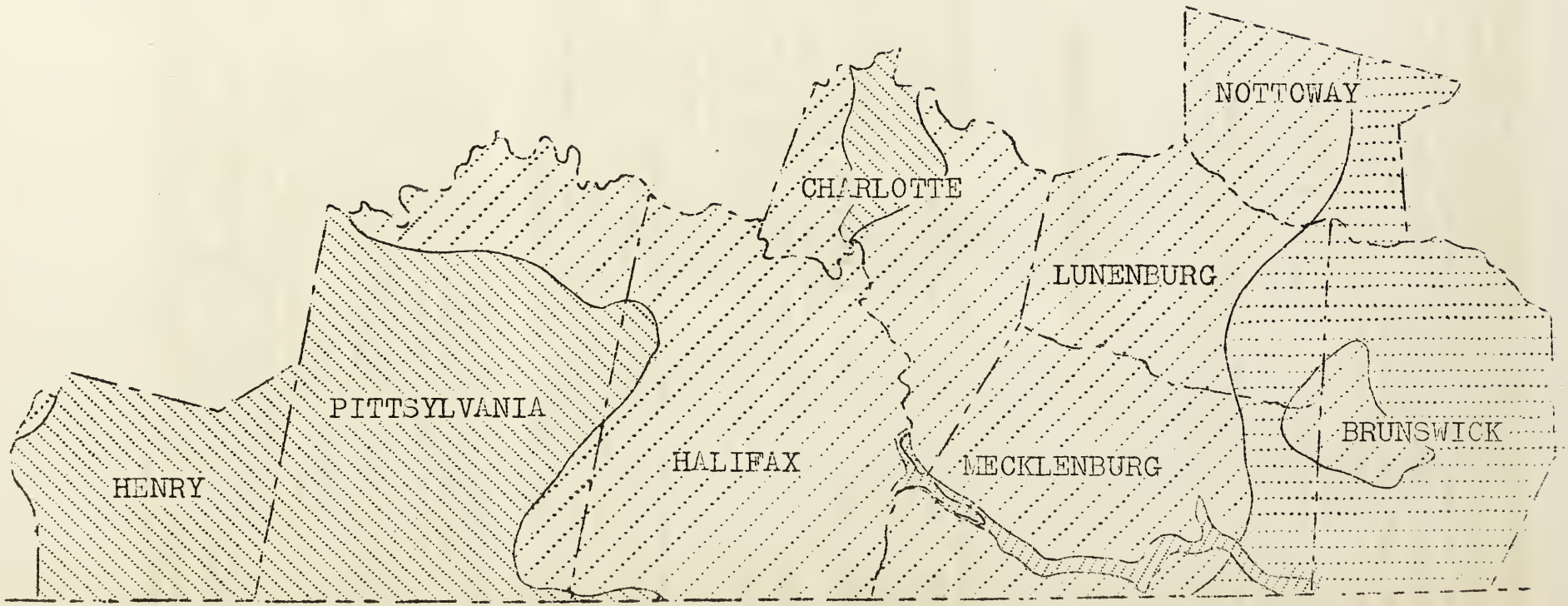
Shortleaf Pine-Hardwoods

Virginia Pine-Hardwoods

Loblolly Pine-Hardwoods

Bottomland Hardwoods

(Adapted from: Major Forest Types, State of Virginia, Appalachian Forest Experiment Station, Forest Survey, 1941.)



Agriculturally, the principal cash crop is flue-cured (bright-leaf) tobacco, although corn occupies a larger area. Grain and cotton are minor crops. Livestock production is increasing. A majority of the population is engaged in agriculture, although primary forest products and furniture manufacture account for 10 percent of all persons employed, and 57 percent of all those engaged in manufacturing.

THE FIRE SITUATION

During the 4-year period from July 1, 1939 to June 30, 1943 (fiscal years 1940-43), 318 fires per year burned 9,147 acres annually in the study-unit, or 0.57 percent of the 1,592,647 acres under protection. Of the area burned, 7,882 acres (86 percent) were forest land. Average size of fire was 28.7 acres, varying from 15.8 acres in 1940 to 42.3 acres in 1942. Largest number of fires per county and year was 101 in Henry County in 1942, smallest number 10 in Charlotte County in 1943. Largest area-burn per year was 3,615 acres in Halifax County in 1942; smallest area was 229 acres in Lunenburg County in 1943. Total area burned in the seven counties ranged from 3,656 acres in 1943 to 20,708 acres in 1942.

Smoking (37.5 percent), brush-burning (33.0 percent), and railroads (11.0 percent) accounted for 81.5 percent of all fires. Incendiary and lumbering fires were 6.0 percent and 2.7 percent, respectively.

In the 4-year period, there was one "bad" year (1942), one "easy" year (1943), and two "average" years (1940-1941) in terms of area-burn. Area-burn ranged from 0.23 percent in fiscal 1943 to 1.30 percent in 1942. Only a very small part of the study-unit is burned oftener than once in 5 years. April, March, and November, in that order, are the peak months of the fire seasons.

The only physical or socio-economic characteristic found correlated with area-burn-percent was percent of tenancy. Burn-percent decreased as percent of tenancy increased, up to the point of 50 percent tenancy, beyond which there appeared to be no further decrease in burn-percent.

The Virginia fire protection organization in the study-area consists of one chief and numerous local wardens in each county, under administrative supervision of a non-technical district forester and the state headquarters staff. There are eight lookout towermen in the area (two towers in one county). Fire-fighters are recruited as needed, although most county wardens have informally organized stand-by crews on whom they can

call. The area under protection is 1,592,647 acres gross, of which 1,407,447[3] acres are forest land and 185,200 acres are sedge-grass fields and brushy pasture.

COSTS OF FIRE CONTROL

By use of various wage rate and commodity price indices, all costs were converted to 1943 wage and price levels, as representative of average dollar values likely to obtain in the forecast period (1944-48). These indices were, where possible, derived from actual records of purchases by the state during the period 1940-43, and otherwise from appropriate indices of the U. S. Bureau of Labor Statistics.

As an example of the method of converting costs expressed in dollar values of year of expenditure to 1943 levels, that used to convert common labor costs is illustrative. Actual wage rates in cents per hour for chief and local county wardens, towermen, fire-fighters, and miscellaneous labor, for each year, were obtained from state records, and also the total expenditures for wages for prevention and suppression activities paid to each class of labor in each year. Costs for each year were then converted into man-hours for each class and later converted to dollars at the 1943 level by multiplying hours by the 1943 hourly wage rate.

In the case of certain items of equipment, recourse was had to the wholesale price index for the whole United States issued by the U. S. Bureau of Labor Statistics. Prices of years other than 1943 were converted to 1943 levels by multiplying by the ratio of the price index of year of expenditure to the 1943 index.

All regular costs (federal, state, county) as reported normally in fire cost statistics were included and in addition certain so-called fixed costs (federal, state, county, municipal, and private), not ordinarily included in reported costs but actually contributing to reduction of area-burn (table 1). The most important fixed cost is that for clearing and burning railroad rights-of-way (71 percent of all fixed costs). Only 30 percent of the total cost of this activity was charged to forest fire protection, however. Contributed time of state game wardens was also an important item of such costs. Fixed costs were 33 percent of the total of all costs.

3/This area is that used by the state in its estimates. It exceeds the area reported by the Forest Survey (p. 3) by about 5,600 acres.

Table 1.—Average annual costs of protection, by source of funds, fiscal 1940-43[1] - Southern Piedmont, Va.

Purpose and source	Regular costs[2]	Fixed costs[3]	Total costs	
			Amount	Percent of total
	$	$	$	
Prevention:[4]				
Federal	5,067.20	533.54	5,600.74	22.8
State	10,521.42	1,551.43	12,072.85	49.1
County	15.00	-	15.00	0.1
Private	-	6,920.57	6,920.57	28.0
Total	15,603.62	9,005.54	24,609.16	100.0
Suppression:				
Federal	697.48	-	697.48	13.7
State	1,005.74	111.03	1,116.77	22.0
County	2,656.80	-	2,656.80	52.4
Municipal	-	604.10	604.10	11.9
Total	4,360.02	715.13	5,075.15	100.0
All Costs:				
Federal	5,764.68	533.54	6,298.22	21.2
State	11,527.16	1,662.46	13,189.62	44.4
County	2,671.80	-	2,671.80	9.0
Municipal	-	604.10	604.10	2.1
All Public	19,963.64	2,800.10	22,763.74	76.7
Private	-	6,920.57	6,920.57	23.3
Grand total	$19,963.64	$ 9,720.67	$29,684.31	100.0
Cost per acre protected, in cents	1.26	0.60	1.85	-

1/All costs are in terms of 1943 dollar values.

2/Includes federal Clarke-McNary (Section 2) funds, state legislative appropriations, and county appropriations.

3/Includes (1) Federal: prorata share of expenditures for Clarke-McNary Law supervision at Washington and Regional Office levels, and for National Wartime Fire Prevention Campaign; (2) State: contributed time of state game wardens, and interest on depreciated value of capital improvements; (3) Municipal: contributed time and expense of equipment-operation by fire departments in suppressing woods fires outside town limits; (4) Private: cost of RR right-of-way clearing and burning, and of locomotive spark arrester installation and maintenance.

4/Includes all presuppression activities.

The total cost, on an average annual basis, of all prevention[4/] and suppression activities in the study-area in the period was $29,684, equivalent to 1.86 cents per acre protected (table 1). Cost per acre varied from 1.84 cents in "easy" 1943 to 2.18 cents in "bad" 1942. Prevention, constituting 83 percent of all expenditures, amounted to $24,609, of which 23 percent was from federal sources, 49 percent state, and 28 percent private. Suppression expenditures, the remaining 17 percent, or $5,075, were 52 percent county, 22 percent state, 14 percent federal, and 12 percent municipal. Of all costs (prevention and suppression), the state provided about 45 percent, federal sources 21 percent, county 9 percent, municipal 2 percent, and private (i.e., railroads) 23 percent.

By functions, at all levels of administration—state, district, and county, administrative salaries and current obligations (rent, insurance, etc.) make up about 30 percent of all costs, common labor makes up 40 percent, and contractual services, supplies, materials, and equipment the remaining 30 percent. The above distribution excludes fixed costs.

In terms of all labor at all levels in man-hours for "regular" cost items, prevention requires 18,196 man-hours, or 11.4 man-hours per thousand acres protected, suppression a total of 10,599 man-hours, or 6.7 man-hours per thousand acres. The combined total is 28,795 man-hours, or 18.1 man-hours per thousand acres protected.

LOSSES FROM FIRE

In evaluating losses from fire, all values at stake and damageable by fire have been considered, even though, in this specific area, the losses to certain items have been negligible or non-existent. All loss data are expressed in 1943 dollars, comparable to those on costs, and where possible, in physical units.

4/In Virginia state records, "prevention" includes all presuppression activities and the term is so used throughout this report.

TIMBER DAMAGE

Losses to timber values were considered from the standpoint of mortality and cull, growth reduction, and stand decomposition. For the mortality and cull phase, use was made of sample plot data already available at this Station. Fire losses to standing timber were evaluated on the basis of "delay to future returns" rather than the "replacement cost" basis. This method gives more conservative values than either the expectation value formula as used by Matthews,5/ or the sinking fund formula. Both formulas give identical values. A discount rate of 2.5 percent, conforming essentially to 1943 yield of long-term taxable bonds issued by the U. S. Government, was used in this and all other discounting procedures in the study.6/

Mortality and cull volumes which the trees destroyed or damaged by fire would have had at maturity were discounted at this rate for the appropriate number of years. The volume which would have been replaced by new trees coming in to occupy the spaces left by burned trees was similarly discounted for the period of years required by them to reach maturity. The difference expresses the present equivalent of future net board-foot losses. These volumes were then multiplied by appropriate dollar values to get total loss. Losses to saw timber, flue-wood, and pulpwood were separately analyzed.

Because of the fact that sufficient stumpage is currently available to meet present requirements for woods operations, hence the activities of woods owners dependent on stumpage would not be curtailed or made financially uneconomic by reason of such fires as occur in the area, stumpage value is regarded as a true expression of the owners' loss from fire. Because some slight increase in operating costs might result, however, an allowance of 5 percent above current stumpage prices has been made to take care of such contingencies.

Total average annual loss to timber (mortality and cull phase) is 4.12 million board feet, plus 7,979 cords of flue-wood, and 1,338 cords of pulpwood. The corresponding total dollar loss is $44,613, equivalent to $4.88 per acre burned and 2.8 cents per acre protected.

5/Matthews, Donald M. Management of American Forests. McGraw-Hill Book Co., New York, pp. 433-435. 1935.

6/Since fire control is a public responsibility, the choice of this rate was dictated by the following considerations: (1) Society must assume responsibility for the future, and is not entitled to discount anticipated benefits at as high a rate as individual time preference would establish; (2) rate of Government borrowing appears to be the closest approximation to social time preference rate.

Because there are no discernible losses to sustained-yield investments, nor to work opportunity for labor, nor to dependent service industries, no secondary social or economic losses are assigned.

No loss is assigned for growth reduction on fire-damaged trees, since there is no evidence of any but a very limited effect on growth rate, other than that already reflected in delayed mortality, from such fires as occur in the area.

Stand decomposition would occur chiefly from crown fires, but surface fires, over a longer period, would also contribute. The procedure for calculating the effect of surface and crown fires on composition of pine-hardwood stands is based on comparison of their values before and after any change due to fire takes place. Changes in value depend on species alteration arising from changed growth rates of component species, and on the varying stumpage values of the component species. Data on file at the Appalachian and Southern Forest and Range Experiment Stations were used to determine these value changes. Fire effects resulting in improved composition of mixed pine-hardwood stands (where crown-killing fires occur but good pine seed trees exist) were also evaluated and the increased value (benefits) deducted from losses.

Total net damage for the entire area in any one year were $365, net benefits $62, leaving a net loss of $303, or $0.038 per acre burned. Assuming an average rotation of 50 years, the $0.038 damage expressed as the present worth of an annual rental at 2.5 percent is $1.08 per forested acre burned, 0.6 cent per forest acre protected, or a total damage of $8,513.

Damage to timber by insects as a direct or indirect effect of fire was also considered. No field evidence could be found of damage to living timber caused by insects which could be traced to fire in the same or an adjacent stand. Ips infestations following the spring 1942 burn were only endemic. Hence no damage is assigned.

In summary, timber damage of all kinds is $58,126, $6.74 per forest acre burned, or 3.8 cents per forest acre protected.

WATERSHED DAMAGE

Watershed value losses consist of (a) increased damages from upland erosion and from flood waters and sediment attributable to fire, and (b) reduction in farm and non-farm well water supplies (groundwater or detention storage) attributable to fire.

Flood, Sediment, and Erosion Damages

Appraisal of this group of damages is based primarily upon data from the Appendices of the U. S. Dept. of Agriculture Flood Control Survey report on the Coosa River Watershed in Georgia, the U. S. D. A. Preliminary Examination Report on the Roanoke River Watershed in Virginia, and the Soil Conservation Service detailed erosion survey of Mecklenburg County, Virginia.

The Coosa report was utilized because it was the only source of the detailed information required to evaluate the effects of fire on storm runoff, erosion, and sedimentation rates. As the main soil association in the Piedmont portion of the Coosa is the same as that within the study-unit, it was possible to make direct application of the above physical rates. These were then related to the amount of erosion damages, and to the downstream damages derived from the Roanoke report.

Major steps in the procedure employed to estimate the effects of fire are indicated below:

(1) Evaluation of average annual direct and indirect flood, sediment, and erosion damages, respectively, for the Roanoke watershed as a whole.

(2) Apportionment of total share of each damage item to the Piedmont province of that watershed. (This was necessary to eliminate the contribution of the Mountain province, with which the study is not here concerned.) Variations in runoff and erosion rates between the two provinces provided the bases for this apportionment.

(3) Each damage item was next prorated among the several runoff or erosion classes of crop, pasture, and forest land within the Piedmont portion, also on the basis of variations in runoff and erosion rates. This procedure provided the share of total Piedmont damages attributable to each erosion class of forest land.

(4) The resulting unit damage figures were then prorated among the several forest land erosion classes in accordance with their distribution within the study-area as indicated by the Soil Conservation Service detailed survey.

(5) Because existing forest land conditions are the result of past logging and grazing, as well as fire, it was necessary to factor out the first two causes of damage. Each erosion class was considered separately, resulting in a figure representing the average annual amounts of flood, sediment, and erosion damage, respectively, attributable to past fire alone.

(6) The next step was to estimate the amount of increased watershed damage due to current fire on the average. Here account was taken of the changes—both in extent and time—caused by the average fire in each forest erosion class. The resulting per-acre damage figures, adjusted to the 1943 price level and multiplied by the average annual area-burn, gave the total average annual monetary watershed damage attributable to forest fires.

Increased damages from "open" lands (sedge fields and scattered brush) included within the protection system were similarly estimated.

Sample Computations

1. Adjusted average annual direct and indirect damages to Roanoke watershed attributable to Piedmont province (1943 price level)..... $ 2,980,500

2. Damages attributable to upland forest conditions in Piedmont..... 1,024,500

3. Amount attributable to past forest fire alone..... 999,700

4. Average annual combined damages per acre, by erosion classes -

Class 1 - (maximum cover density; no erosion, minimum runoff).....	$ 0.00
Class 2-3 - (good overstory but poor ground cover due to fire; medium erosion and runoff).....	0.46
Class 4-6 (low total density; high runoff and erosion rates).....	1.05
Average (weighted by area).....	0.48

(Comparable damage from "open" land is $0.06.)

5. Average annual increased damage caused by fire on existing erosion classes, as shown by table 2.

Table 2.--Increased watershed damage caused by average annual fire on forest lands (per-acre basis) - Southern Piedmont, Va.

Before fire		After fire			Damage due to fire	
Forest erosion class	Average annual damage	Erosion class	Damage first year: Range	Damage first year: Average	First year--Column 5 less Col. 2	Average annual equivalent
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	$0.00	2-6	$0.23-1.05	$0.64	$0.64	$3.20
2-3	.46	$3-6_c$ 1/	.69-2.10	1.40	.96	4.81
4-6	1.05	6	2.10	2.10	1.05	5.26

1/Class 6_c is equivalent to poor crop land condition.

Water-Yield Losses

Water-yield losses in the Piedmont arise out of the same causes that contribute to erosion, floodwater, and sedimentation damages. The direct effect is the lowering of the infiltration capacity of the soil, hence to receive rainfall for storage and slow release. The major source of water supply within the study-unit is from groundwater obtained through wells, and rainfall is the ultimate source of groundwater. Reductions in the amount of water entering the soils are therefore sooner or later reflected in reduced yields of well water.

Reduction in groundwater storage was estimated after field check of infiltration rates and by consultation with water resource engineers and personnel of the Soil Conservation Service drainage research project at Chatham, Virginia.

Analyses of average annual loss caused by fire to groundwater storage, expressed in acre-inches, gave the following results for the major types of land in the study-unit:

Old-field pine	0.80 acre-inch per year
Old-field hardwoods	0.27 " " " "
Natural woods	0.05 " " " "
"Open" land	1.00 " " " "

These losses are not permanent, however, the evidence indicating that the "pre-burn" soil-water relations will be restored in each of the above classes by about the sixth year after the average fire. Expressed in volume, the total loss over the 5-year period of record is calculated at over 558 million gallons.

The effect of a single average burn on detention storage of groundwater is shown in figure 2.

The monetary evaluation of water-yield losses is based upon the difference between the average cost of producing current well-water supplies and the cost of producing alternative or more satisfactory supplies either from wells or from surface sources. Separate estimates were made for farm and non-farm consumer groups, the latter including both domestic and industrial consumers in population centers.

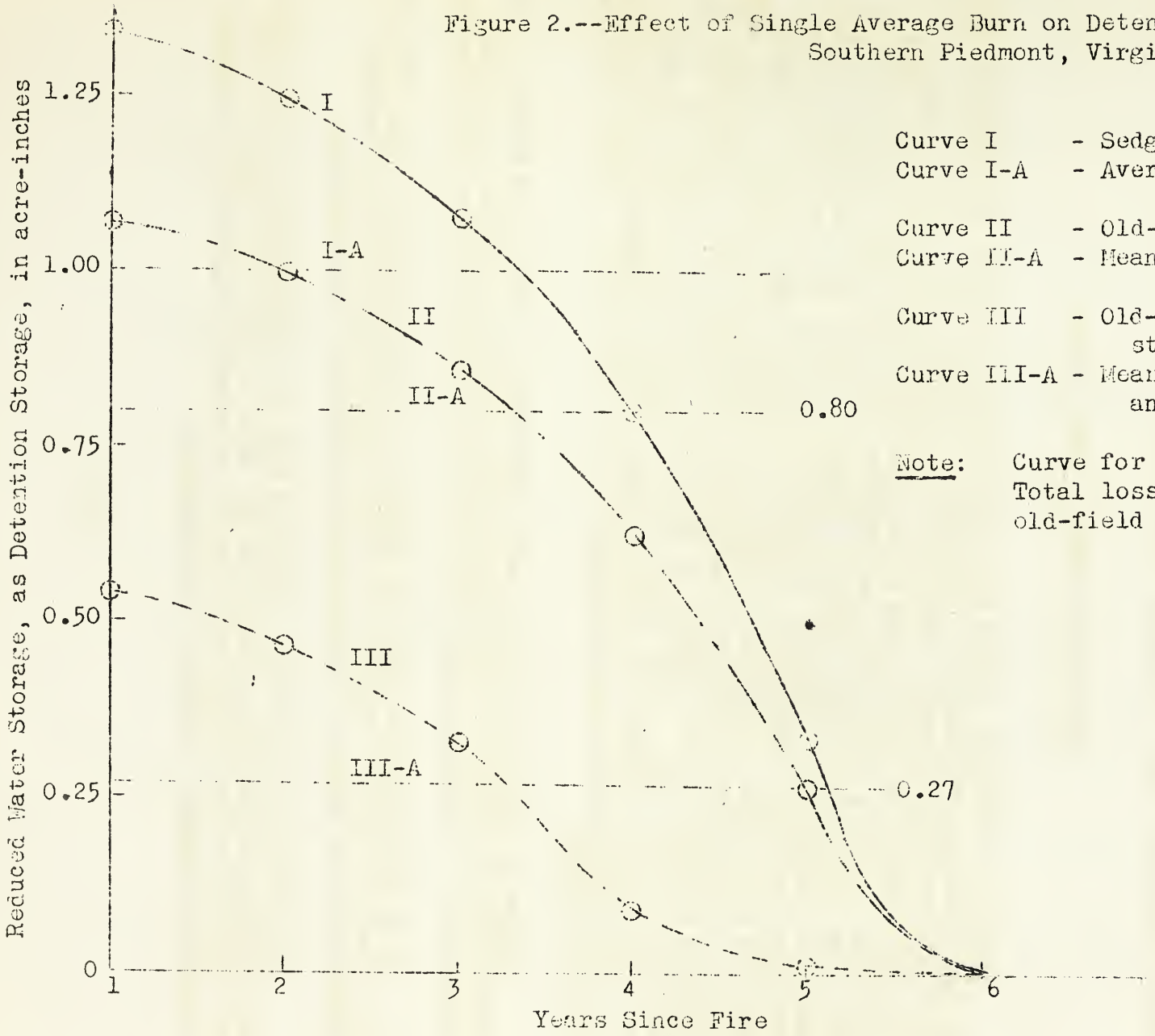
The problem of overcoming water shortages is causing increasing concern throughout the Piedmont. In general, well supplies on farms and in communities are proving inadequate to meet existing demands. Water restrictions continue to be in force in many communities, and farmers are finding it more difficult to satisfy their requirements.

Water resource engineers indicate that, as in the case of the North Carolina Piedmont, the solution to the non-farm water supply problem lies mainly in the impoundment of surface waters. For this reason the unit cost of alternative supplies for this class of consumer is based upon reservoir development. Farmers, however, must seek a solution to their problems mainly by substituting deeper drilled wells for the shallow dug wells now prevailing. Therefore the measure of the loss here is the difference between present and future unit well supply production costs.

Costs of both current and alternative supplies were calculated after interviews with water resource engineers, the U. S. Geological Survey, and well-drilling companies, and after review of the literature on waterworks engineering, including a report by the Soil Conservation Service on reservoir sedimentation in the North Carolina Piedmont. Illustrative data follow:

	Cents per 1,000 gals.
(1) Current water production costs	
(a) Farm well supplies	8.0
(b) Non-farm well supplies (exclusive of cost of putting water through distribution systems)	5.0
(2) Alternative costs of water supply	
(a) Farm (deeper drilled wells)	10.7
(b) Non-farm (reservoir development)	12.0
(3) Increased unit costs (2) minus (1)	
(a) Farm	2.7
(b) Non-farm	7.0

Figure 2.--Effect of Single Average Burn on Detention Storage of Ground Water, Southern Piedmont, Virginia



Curve I - Sedge field and scattered brush land.
Curve I-A - Average annual loss, open land as above.

Curve II - Old-field pine stands.
Curve II-A - Mean annual loss, old-field pine stands.

Curve III - Old-field pine-hardwood and pure hardwood stands.
Curve III-A - Mean annual loss, old-field pine-hardwood and pure hardwood stands.

Note: Curve for natural woods not plotted. Total loss estimated at 1/6 of loss from old-field hardwood stands.

	Cents per 1,000 gals.
(4) Weighted average annual increased cost, all consumer classes, based upon farm daily per-capita consumption of 25 gallons, and non-farm consumption of 75 gallons	5.2

As previously indicated, the losses from a given fire extend over a limited period during which they continue to decline. Therefore the above unit cost was not multiplied directly by the average annual volume of water-yield losses. Instead, the monetary values of the losses for each year of the 5-year period were discounted back to the present time. The sum of these discounted values, representing the loss caused by fire on the average each year amounts to about $28,000, or $3.01 per acre burned, and 1.7 cents per acre protected (table 3).

WILDLIFE AND RECREATIONAL DAMAGE

Losses to wildlife values were evaluated in respect to direct damage to game animals, and damage to habitat. Principal game birds in the area are quail and wild turkey. Woodcock and mourning-dove, also present, are less susceptible to damage from fire. Principal fur-bearers are rabbit, squirrel, opossum, skunk, fox, and raccoon, the last three species being much less abundant than the others. Almost no data are available on fire damage to wildlife in Virginia or comparable areas, nor are data on game frequency available except for quail and turkey. Hence losses to these two game birds were evaluated on only an approximately factual basis, while damage to other game birds and animals was estimated from a consensus of informed persons. Total number of quail lost by fire is estimated at 290 per year for the area, worth $725, at an assigned dollar value of $2.50 per adult bird, a figure set by the state. Turkey losses are small, only one bird estimated as being destroyed in the area burned. Adult replacement value is $12.50.

Losses to other game birds were estimated at $25.00 per year, and to fur-bearers at $50.00. Total loss to game animals, therefore, is $812, equivalent to 9 cents per acre burned, and to 0.05 cent per acre protected.

It is the consensus that the effects of the relatively small fires in this area on wildlife habitat are about equally beneficial and detrimental—that no damage to habitat should therefore be assigned.

Recreational values were analyzed from the standpoints of (1) organized outdoor recreation, limited in the area to two state parks (one in, one adjacent to the study-area) and (2) unorganized recreation, limited largely to hunting, fishing, and trapping.

Table 3.--Summary of all losses from fire, average annual basis, Southern Piedmont, Va.

Item damaged	Total loss (1943 values)	Loss per acre burned[1]	Loss per acre protected[2]	Physical units	
				Unit	Amount
	Dollars	Dollars	Cents		
Timber Values:					
Mortality and cull phase	44,613	4.88	2.80	(MBF (Cords	4,120 9,317
Insect damage	None	-	-	-	-
Stand decomposition	8,513	0.93	0.53	-	3/
Total timber	53,126	5.81	3.33	-	-
Watershed Values:					
Floodwater, erosion, etc.	35,270	3.86	2.22	-	3/
Groundwater loss	27,565	3.01	1.73	1000 gals.	558,163[4]
Total watershed	62,835	6.87	3.95	-	-
Wildlife Values:					
Direct to animals	812	0.09	0.05	Number	(290 quail (1 turkey
Habitat	None	-	-	-	-
Recreational Values:	None	-	-	-	-
Grazing Values:	None	-	-	-	-
Social & Economic Effects:	Negligible	-	-	-	-
Other Property Values:[5]	8,238	0.90	0.52	-	3/
Other Losses:[6]	Negligible	-	-	-	-
Total - All Losses	125,011	13.67	7.85	-	-

1/Total area burned, 9,147 acres--used for each item.
2/Total area protected, 1,592,647 acres--used for each item.
3/Cannot be expressed in physical units. See text for discussion.
4/Loss during 5 years following fire.
5/Farm buildings, fences, forest products.
6/Non-monetary items such as loss of life, interference with travel, and with fire detection system.

Although use of the two state parks is intensive, with an estimated return (from fees, etc.) per forest acre of $19.63, and although potential damageability from fire is therefore high, in matter of fact not a single acre of either park has been burned in the 7 years they have been established. As this period includes two severe fire seasons, it is assumed that there is very little likelihood of damage to these recreational values.

The area does not rank with either the coastal plain or mountain regions for hunting and fishing. Only 10,239 hunting, fishing, and trapping licenses of all kinds were issued in the average year, in an area with 175,000 population.7/ With the low loss from fire to game, noted previously, it is evident that fire would have no effect on sale of licenses or use of the area for these purposes. The authors conclude, therefore, that fire causes no damage to recreational values in the study-area.

OTHER DAMAGE

Damage to "other property" as defined herein was taken directly from the county summaries of the wardens' fire reports. Items included are forest products (both rough and manufactured), farm buildings, fences, grazing values, and miscellaneous property. Details of the component proportions of items included in the total are not available, but farm outbuildings and fences are believed to be the principal items, and forest products the next largest item. Losses for 1940-42 were converted to 1943 values by use of the best index obtainable for the period--prices paid by farmers for building materials other than those used in dwellings. Total loss to "other property", in 1943 values, is $8,238 per year, or $0.90 per acre burned, and 0.5 cent per acre protected.

As indicated in the discussion of timber losses, no damage to the general "public interest" was assigned to these losses. The low burn-percent, lack of conflagration-type fires either actual or potential, and present availability of timber all indicate insignificant fire effects on the social and industrial economy of the area. The same is true of damage to such non-monetary values as loss of life (none of record), interference with travel, or decreased efficiency of the fire detection system. Such losses as may accrue to either the social-industrial economy or to these non-monetary values are negligible and no dollar values are assigned to them; nor are they of sufficient consequence to take into account in determining the maximum justifiable expenditure for fire protection.

7/Under Virginia law, the owner of land and his family may hunt on his own land without a license, so the sale of licenses is not wholly indicative of extent of hunting in the area.

SUMMARY OF DAMAGES

The total average annual damage from fire to all values at stake and damageable by fire in the Southern Piedmont of Virginia is $125,011, or $13.67 per acre burned and 7.85 cents per acre protected. Timber losses are 42 percent; watershed losses, 50 percent; and other losses 8 percent of all damage (table 3).

DETERMINATION OF JUSTIFIABLE PROTECTION COST

Having determined the total costs of fire control and the total losses from fire, it is now in order to determine the justifiable protection cost--the point at which the sum of costs and losses is at the minimum. The steps in this procedure are as follows:

(1) Determination of relation between average annual area-burn-percent and average annual protection cost per acre.

(2) Determination of variations in cost and burn-percent from average annual to worst and easiest fire years, respectively.

(3) Plotting of sum of cost plus loss per acre protected over protection cost per acre, and reading of curve.

These steps are briefly discussed in the order given.

Attempts to derive a curve of area-burn-percent over cost per acre from the study-area data, or from those of the State of Virginia, as a whole, were unavailing because the net effect of costs on area-burn was obscured by other variables and the range of costs was too small. With these unadjusted data, statistical analysis indicated that the greater the cost, the greater the area burned, a relation which leads to an absurdity.8/ Hence to provide a broader base, data were used from eight northeastern states (including Virginia) for the period 1931-43, inclusive. Data for the CCC years (1934-40) were analyzed separately from the pre- and post-CCC years (1931-33 and 1941-43), the latter two groups

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8/Area-burn-percent was used rather than dollar losses in deriving these curves because damage data were not available outside the study-area. Dollar losses are closely correlated with area-burn for any given period, if changes in dollar values within this period are accounted for in the analysis.

of years being combined to derive the master curve of area-burn over cost. By statistical techniques, various factors affecting the net relation of cost and area-burn were eliminted. These factors were: (1) difference in size of area protected, (2) length of fire season, (3) purchasing power of the fire control dollar. This eliminated all factors except cost, burning-index, and annual number of fires. These were included in a multiple correlation analysis. The final multiple regression equations were as follows:

Non-CCC years: $x_1 = 0.9756 - 0.2578\ x_2 + 0.1865\ x_3 + 0.0356\ x_4$

CCC years: $x_1 = 0.5560 - 0.2145\ x_2 + 0.1744\ x_3 + 0.0445\ x_4$

where:

x_1 = percent annual burn per 100 class-3 days,

x_2 = cost per acre per year of 100 class-3 days,

x_3 = burning index,

x_4 = number of fires index.

Five successive adjustments for curvilinearity in the various relationships were made to derive the final curves showing the net relation of percent area burn to cost per acre for each period (figure 3; for non-CCC years). The curve for the non-CCC years was then adapted to Southern Piedmont Virginia conditions, first by adjusting it to the proper length of season and to dollar values, and second by adjusting it, by proportional reduction, to pass through the specific area burned-cost data. This final curve (figure 4, Curve I) has been used as the basis for determining the cost-loss ratios and least cost-loss point for the study-area.

To show the deviation from the average annual curve of area-burn on cost caused respectively by a "bad" year (1942) and an "easy" year (1943), comparable curves were derived by the method of proportional reduction or increment for 1942 and 1943 (figure 4). These curves indicate that severity of season has a marked effect on area-burn irrespective of cost—that is, the same cost per acre expended in the "average" year (mean of 1940-43) resulted in a much lower burn-percent than the same cost per acre in 1942, and conversely, a much higher burn that in 1943.

The procedure used to derive the cost-loss ratio curves (average annual, for 1942, and for 1943, respectively) was to plot the values of total cost-plus-loss per acre protected for each cent of cost per acre over cost per acre in cents for each period (Curve I, figure 5, for average annual, Curve II-1942, Curve III-1943). The point at which each

Figure 3.--Final Curve for the 1931-33 plus 1941-43 data, for a season of 100 class-3 days or the equivalent, in 8 eastern states (Conn., N. Y., Pa., Md., W. Va., Va., N. C., Tenn.)

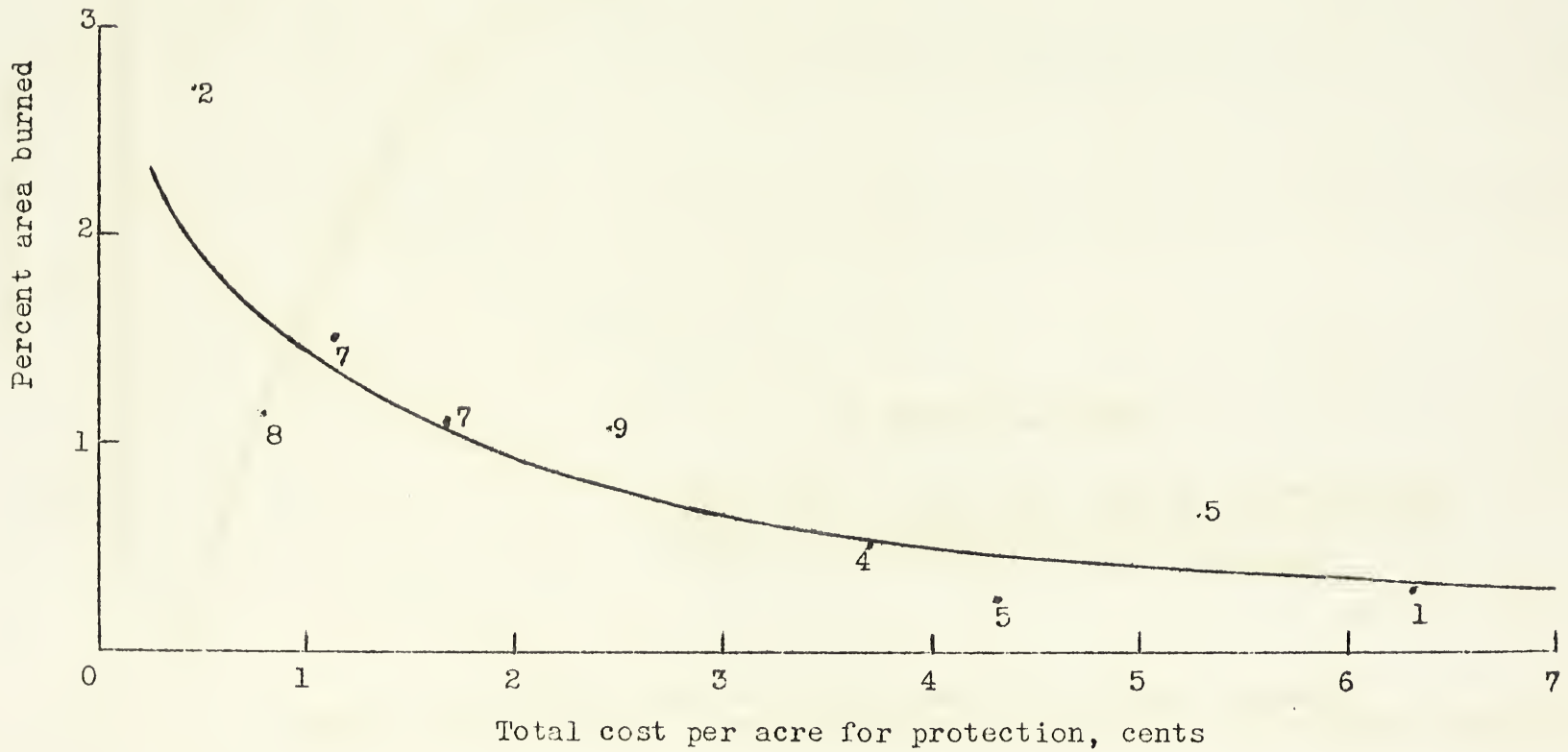
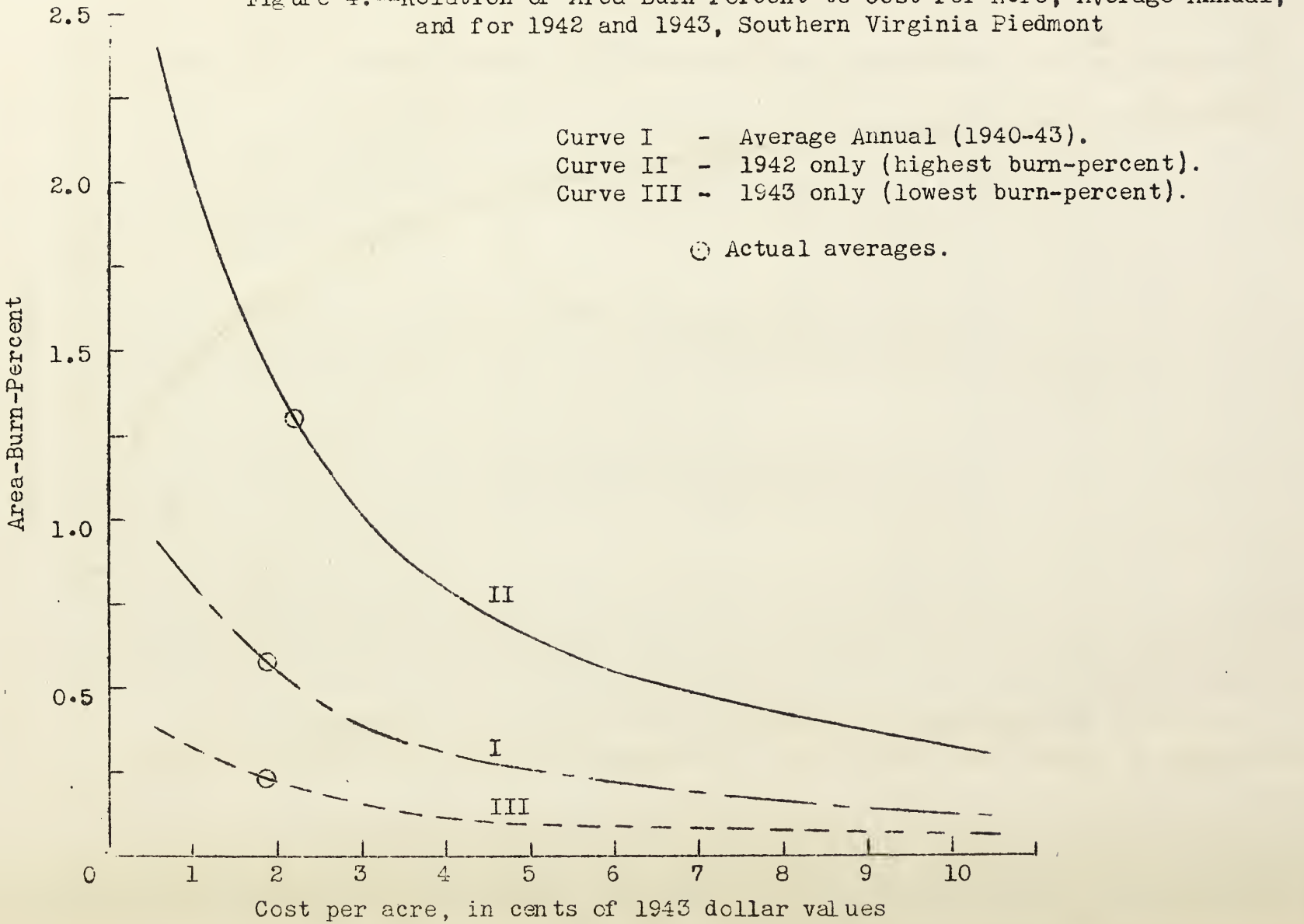


Figure 4.--Relation of Area-Burn-Percent to Cost Per Acre, Average Annual, and for 1942 and 1943, Southern Virginia Piedmont



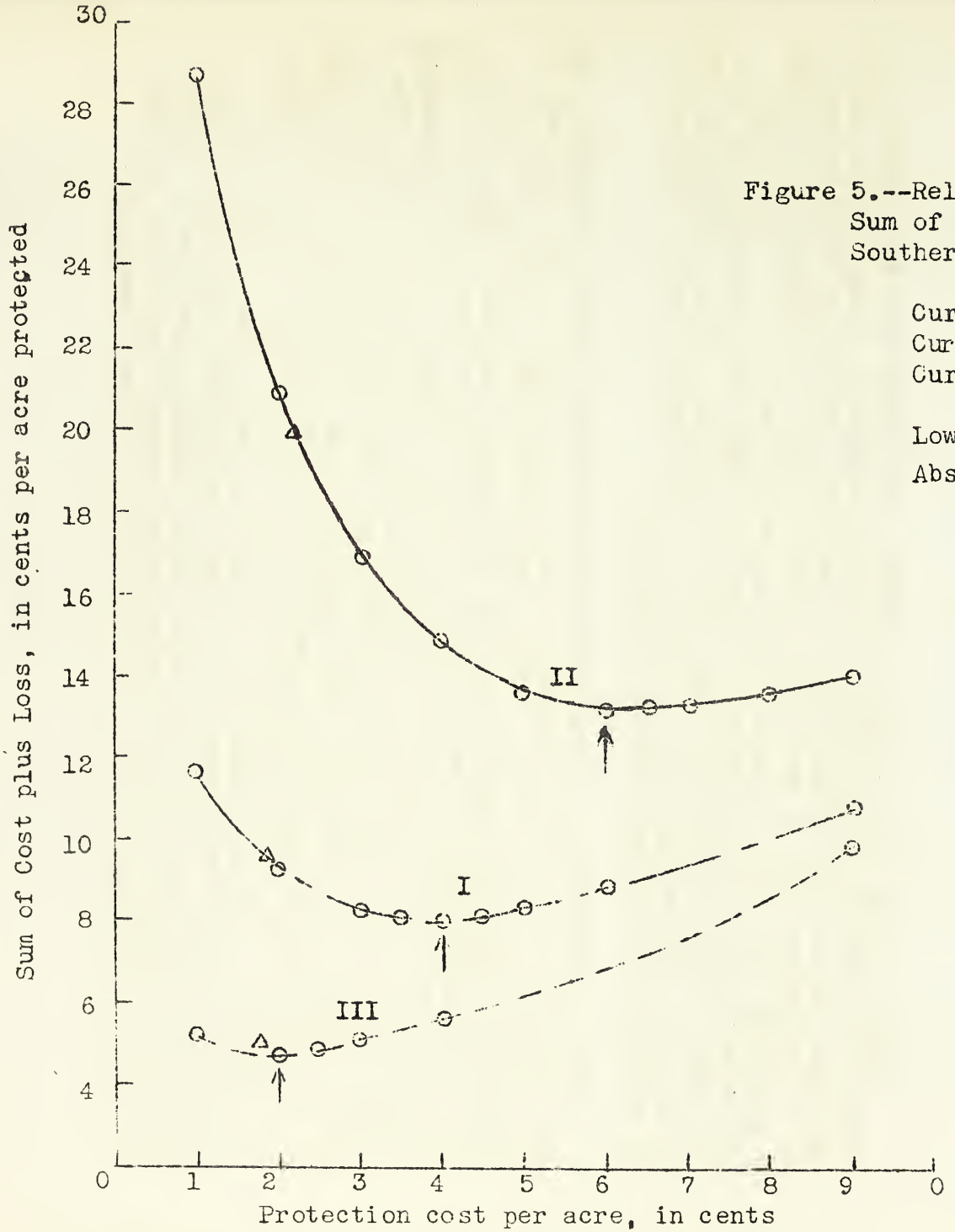


Figure 5.--Relation of Protection Cost per acre to Sum of Costs and Losses per acre, Southern Piedmont, Va. - 1940-43.

Curve I, Average Annual - 1940-43.
Curve II, 1942 (worst fire year)
Curve III, 1943 (easiest fire year)

Lowest cost plus loss point - ▲
Absolute averages..... △

of these curves approaches closest to the x-axis is obviously the point at which the sum of cost and loss is lowest for the year or period indicated.

For the average year in the study-area (Curve I, figure 5), the lowest cost-loss point (or the economic limit of justifiable expenditure) is 4.0 cents per acre. Any expenditure beyond this point would, at least in theory, increase costs more rapidly than it decreased loss, and therefore would be uneconomic. For example, to increase the expenditure by 0.5 cent (to 4.5 cents per acre) would decrease loss per acre by only 0.4 cent (to 3.7 cents per acre). To increase expenditures by 1.0 cent (to 5.0 cents per acre) would decrease loss by only 0.7 cent (to 3.4 cents per acre). Hence, for every unit of cost above 4.0 cents the input of cost is greater than is recouped in damage reduction.

IMPLICATIONS OF FINDINGS

Figure 5 shows that in 1942, however, the lowest cost-loss point is between 6.0 and 6.5 cents, while in 1943 it is at 2.0 cents. These curves emphasize the need for flexibility in available protection funds because it is recognized that no protection organization can maintain at all times a permanent force able to meet fully the requirements of the occasional bad season unless it is willing to spend its funds uneconomically in normal years. Nor, on the other hand, can it maintain a force sufficient only to meet the requirements of easy years, or even average years, unless it is willing to face heavy losses in bad years.

For the study-area, under present conditions of forest ownership, use, and management, and over a period of years, 4.0 cents per acre per year is the justifiable limit of fire control expenditure—the optimum level of protection, provided provision is made for making available funds to meet the added requirements of such years as 1942. Such reserves might be created by fiscal provisions for impounding to the credit of the Conservation Commission for use in protection activities the unexpended balances from "easy" years (i.e., all years requiring less than 4.0 cents per acre), such reserves to be available until expended. An alternative method might be the creation by legislative appropriation of a protection contingency (or sinking) fund to be maintained at such level as the General Assembly may determine. If maintained at a reasonable level, such a fund might well make possible the reduction of annual legislative appropriation for protection below 4.0 cents per acre. These proposals are merely illustrative of possible methods of achieving the needed flexibility of fund availability indicated by the cost-loss curves for this study-area.

The most "profitable" expenditure of 4.0 cents per acre per year is indicated only for the existing type of fire control organization. Conceivably, radical changes in fire control systems might so change the area burned-cost relation as to give an entirely different cost-loss minimum. It was not within the scope of the present study to compare the effectiveness of fire control organizations and the bearing thereof on the lowest cost-loss point.

An expenditure of 4.0 cents per acre9/ would reduce area-burn-percent in this area to 0.30 as contrasted to present burn-percent of 0.57 at a cost of 1.86 cents. This cost of 4.0 cents includes 0.6 cent of "fixed" costs, so the "regular" costs would be 3.4 cents per acre, as contrasted to the present 1.27 cents. Total cost at the 4.0-cent level would be $63,706, of which $9,721 are fixed, and $53,958 are regular. The increase over present total costs is $34,021, all in regular funds, since fixed costs would, by definition, be unchanged.

The recently approved law, effective July 1, 1945, requiring each county to repay into the state treasury all money expended in it by the state for all protection activities, at a rate not to exceed one cent per year per acre of private forest land in said county, will provide, if the full levy is collected in each county annually, the sum of $14,018, an increase of $11,346, or 425 percent over present county contributions. The remainder of the $34,021 increase ($22,675) would come from federal and state sources.

The effect of the 4.0-cents-per-acre rate on labor requirements would be to reduce labor for suppression (concomitant with reduced area-burn) from 6.7 to 3.9 man-hours per thousand acres protected, and to increase prevention labor requirements from 11.4 to 37.7 man-hours per thousand acres, or a net increase from 18.1 to 41.6 man-hours, for all activities, per thousand acres protected, a total net increase for the area of 37,459 man-hours.

Analysis of data on the recommended land-use conversions of the three Soil Conservation Districts in which the study-area is located, and of progress in that program to date, plus opinions of qualified foresters in the area and the authors' observations all lead to the conclusion that no changes in forest ownership, use, or management in the area are likely to take place during the forecast period which would affect the costs of fire

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9/Note must be taken that these expenditures are in terms of 1943 dollar values. If it is desired to determine costs at 1946 levels, it will be necessary to adjust the costs here shown to then prevailing dollar values.

control. Hence the authors conclude that the rate of 4.0 cents as the optimum level of protection will apply through 1948.

APPLICABILITY TO OTHER AREAS

The findings of this study have not been tested as to applicability outside the study-unit, nor are such tests now contemplated. The authors believe, however, that the findings apply to two outside areas, one lying immediately to the north in the Virginia Piedmont, consisting of all or parts of eight counties, and one lying to the south in the North Carolina Piedmont, consisting of 10 counties (fig. 6).[10/] The latter area is not now under cooperative Clarke-McNary protection, however, so the findings could not be applied directly until such time as it is duly organized and basic physical facilities are provided. The findings do not apply either to the mountain section or to the coastal plain section of Virginia.

No specific recommendations as to record keeping or damage appraisal techniques are made at this time. Those which have tentatively been developed from the Southern Piedmont study related to procedures applicable throughout the state rather than to the study-area alone. Inasmuch as the Southern Piedmont is only one of several case study-areas to be studied, the authors deem it wiser to test their tentative recommendations against research in these other areas before presenting them for consideration.

10/Pittsylvania County, Va., while excluded from the study-area data, lies within the unit, and the results are applicable to it.

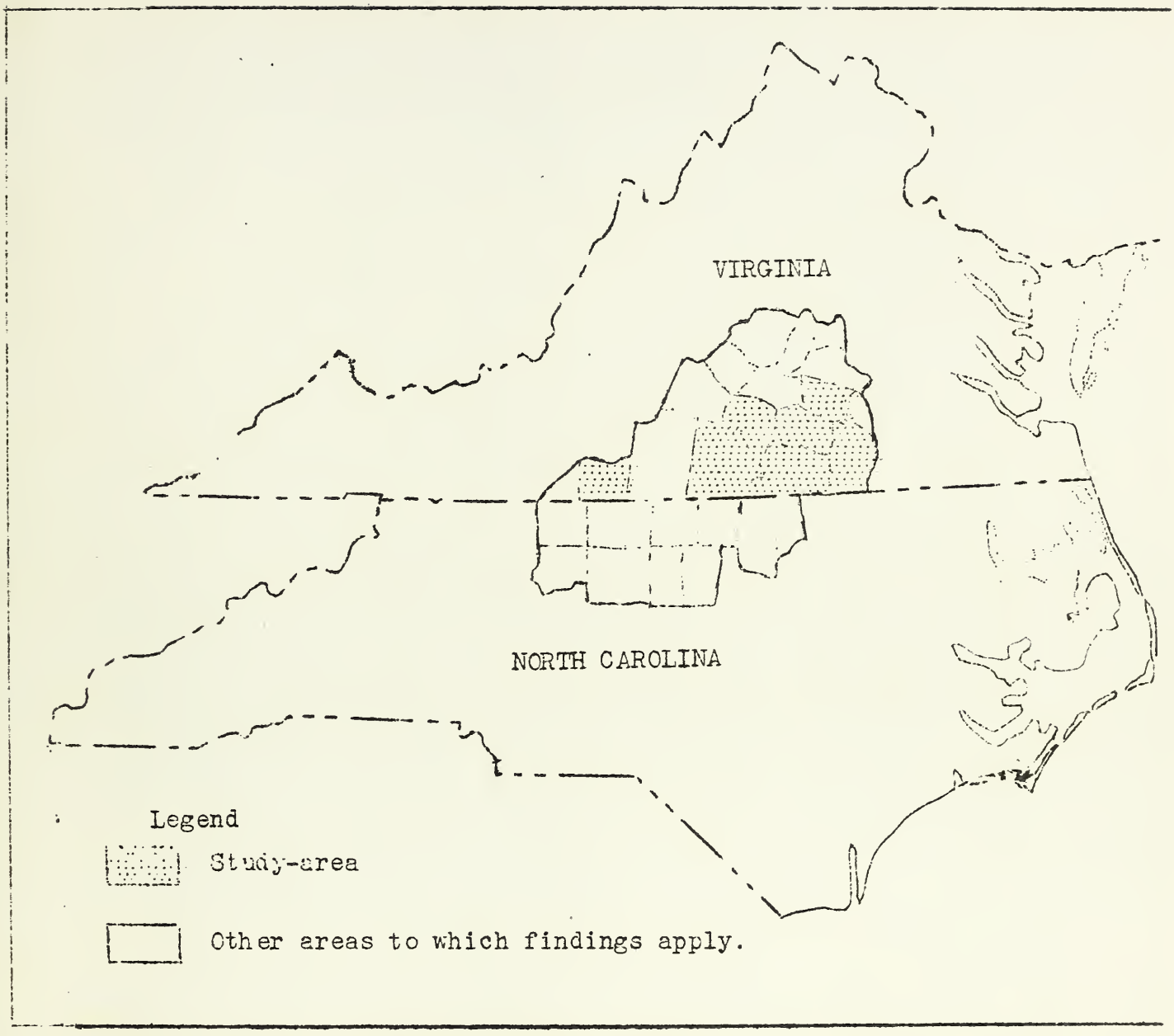

Figure 6.--Applicability of Findings to Other Areas.